AOT & LANSCE The Pulse

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INSIDE

Yusheng Zhao

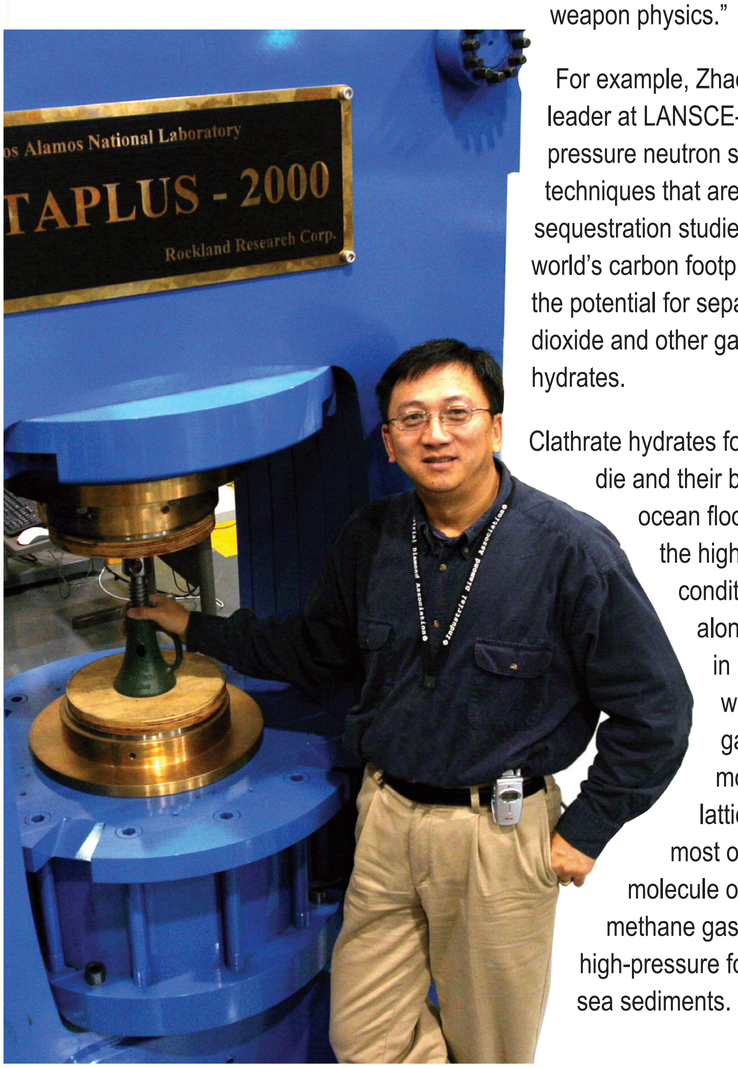
Pioneering high-pressure, neutron-scattering scientist

By Rosemary Rehfeldt, Communications Arts and Services

For more than 15 years, Yusheng Zhao has been on a scientific journey probing the center of the Earth. A scientist at Los Alamos National Laboratory's Lujan Center (LANSCE-LC), Zhao combines high-pressure mineral physics research—studying the deep interior of the earth—with innovative neutron-scattering techniques to produce a variety of groundbreaking applications.

Zhao balances fundamental physics research with engineering innovations.

According to Lujan Center Director Alan Hurd, Zhao has "developed a program that combines high-pressure technology with his pioneering research in neutron scattering techniques, leading him to create highly productive programs in superhard materials, renewable energy, and weapon physics."



For example, Zhao, the high-pressure team leader at LANSCE-LC, developed novel high-pressure neutron scattering and imaging techniques that are used in carbon dioxide sequestration studies aimed at reducing the world's carbon footprint. This research examines the potential for separation and capture of carbon dioxide and other gases in natural clathrate hydrates.

Clathrate hydrates form as oceanic life-forms die and their body decomposition on the ocean floor forms methane gas. In the high-pressure, low-temperature conditions at the ocean's bottom, along continental shelves, and in permafrost at the poles, water reacts with the methane gas to form crystallized water molecules that create a rigid lattice of cages, a clathrate, with most of the cages containing a molecule of natural methane gas. The methane gas is trapped or dissolved in high-pressure form, ice, within these deep-sea sediments.

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Vogel receives LANSCE Director's Excellence Award

Sven Vogel (LANSCE-LC), one of the world's leading experts on the use of neutron diffraction to study materials microstructure, was awarded the 2009 LANSCE Director's Excellence Award by Kurt Schoenberg (ADEPS) for his achievements in publishing papers with scientists from around the world on materials transformations, especially geomaterials. H.R. Wenk (University of California, Berkeley) and Lujan Center Director Alan Hurd nominated him.

Vogel established a completely new effect in materials science, "texture memory," in studies of phase transitions in quartz with Wenk on the Lujan High-Pressure Preferred Orientation Diffractometer (HIPPO) instrument. This first prominent result from HIPPO was reported in "Neutron Production, Neutron Facilities and Neutron Instrumentation," *Reviews in Mineralogy* **64**, (2006).

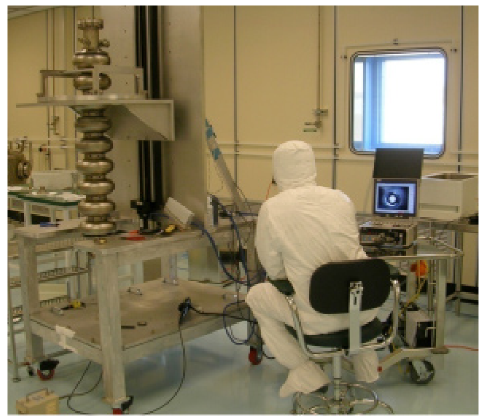
Roger Pynn established the LANSCE Director's Award in 1999, to recognize the scientific excellence and leadership of a Los Alamos staff member strongly involved with LANSCE, either through their own research program, collaborations with LANSCE users, or programmatic development of the scientific program at LANSCE.

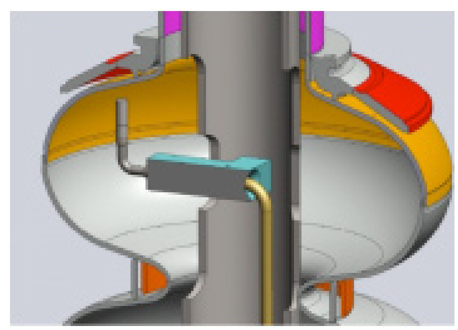
Accelerator structure development and thin coating on niobium samples

Niobium (Nb) superconducting radio-frequency (SRF) cavities have been used for the acceleration of beams in various particle accelerators for high energy physics, nuclear physics, materials science, biology and medicine due to high energy efficiency and better features compared to conventional copper structures.

While the achieved accelerating gradient has increased from 5-10 MV/m in the 1980s to 30-40 MV/m in the 2000s, 50-60 MV/m seems to be the limit of bare Nb SRF cavities due to its RF critical magnetic field of ~200 mT. This limit prevents new projects requiring higher gradient and compact accelerators from considering SRF structures.

Research being performed by Tsuyoshi Tajima and Grigory Eremeev (AOT-MDE) in collaboration with researchers from MST and MPA has the potential to overcome this limitation, resulting in the construction of more compact and cost efficient accelerators. Their approach is based on the theory that predicts breaking through this limitation by coating thin superconductors on niobium. In collaboration with SLAC National Accelerator Laboratory, they initiated measurements of RF critical magnetic fields of Nb coated with various thin film superconductors.





Above: Inner surfaces of a 1.3 GHz 9-cell cavity is being inspected in a clean room. Top right: A 9-cell cavity with 4608 temperature sensors attached on the outer surface for diagnostics. Bottom right: A three-dimensional model that shows how the cavity surface is inspected using a videoscope.

First results with 100 nm of MgB_2 deposited on single-crystal niobium disk, presented at the 9th European Conference on Applied Superconductivity and 14th International Conference on RF Superconductivity, indicated that a high quality MgB_2 film with the superconducting transition temperature 4 times higher than that of Nb was deposited. The critical magnetic field of the system, however, was significantly lower than that of pure niobium, indicating that further studies are necessary to optimize deposition parameters.

Future plans are to investigate this breakdown phenomenon and test more samples with various thicknesses and layers.

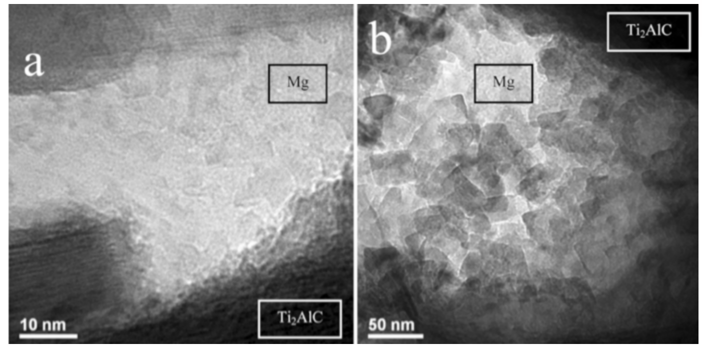
From Los Alamos, collaborators include Tony Burrell (MPA-MC), Quanxi Jia and Guifu Zou (MPA-STC), Roland Schulze (MST-6), and Kevin Baldwin (MPA-CINT) as well as researchers from the Stanford Linear Accelerator Center and Superconductor Technologies, Inc. (both in California) and Oak Ridge National Laboratory. The work is supported by DTRA.

Nanograins demonstrate extraordinary thermal stability

Nanoscale structure gives nanomaterials enhanced physical properties, compared with bulk materials. However, applications of some nanomaterials have a limited temperature range to prevent the growth of grain size.

Luc Daemen (LANSCE-LC), Michel Barsoum (LANSCE-LC and Drexel University), and collaborators (Drexel University, Linkoping University, Sweden; University of Pennsylvania; and University of Delaware) discovered extraordinary thermal stability of magnesium nanograins in a titanium-aluminum-carbon-magnesium composite. X-ray diffraction and neutron spectroscopy indicate that a thin, mechanically robust layer separates the magnesium nanograins and prevents them from solidification stresses during the temperature cycling. The microstructure is so stable that heating the composite three times to 50 °C beyond the melting point of the bulk magnesium does not lead to growth of the grain size.

Making nanoscale materials economically and on an industrial scale is a challenge because nanosized powders must remain non-agglomerated and mono-dispersed during synthesis and consolidation. Processing the magnesium nanograin matrix composites is a simple process that uses pressure-less melt infiltration, resulting in magnesium grains of ~20-40 nm in size.



Transmission electron microscopy images of the magnesium nanograin matrix in the (a) hot pressing and (b) melt infiltration Ti_2AlC composite samples.

The material is readily machinable, light, relatively stiff, strong, and exhibits ultrahigh damping. The combination of excellent mechanical properties and thermal stability should provide a broad range of potential applications.

Reference: "On the Stability of Mg Nanograins to Coarsening after Repeated Melting," *Nano Letters* **9**, 3082 (2009). The Wheatley Scholarship of the LANSCE Lujan Center (Michel Barsoum) and the DOE Office of Basic Energy Sciences funded the Los Alamos portion of this work.

Competitive adsorption of lung surfactant and albumin

Lung surfactant is a slippery, complex mixture of lipids and proteins that helps the lungs inflate with air and keeps the air sacs (alveoli) from collapsing. Acute respiratory distress syndrome occurs when pulmonary capillaries leak blood serum proteins (especially albumin) into the alveoli. The leakage prevents the lungs from filling with air and can result in a dangerously low level of oxygen in the blood. Understanding the fundamental biophysics and surface chemistry of lung surfactant can lead to therapeutic treatment. Clinical research shows that the presence of hydrophilic non-adsorbing polymers within the same subphase helps the lung surfactant overcome the effects of albumin.

Chad Miller and Jarsoslaw Majewski (both LANSCE-LC), and collaborators (University of California, Santa Barbara, University of Chicago, and RisØ National Laboratory, Denmark) used x-ray reflectivity and grazing incidence x-ray diffraction to examine competitive adsorption of lung surfactant and albumin at the air-water interface as a model for behavior in the lung. Equilibrium favors lung surfactant as it has the lower equilibrium surface pressure, but the smaller albumin is kinetically favored by faster diffusion. The scientists added Survanta, is a clinical lung surfactant used to treat acute respiratory distress syndrome. Survanta reduces the surface tension of fluids inside the lung, preventing collapse of the lung. Albumin induces a slightly larger lattice spacing and greater molecular tilt of the phospholipid phase fraction of Survanta, similar in effect to a small decrease in the surface pressure. Adding the water soluble polymer, polyethylene glycol (PEG), to the Survanta and albumin containing subphase restores the characteristic Survanta electron density profile at the interface and confirms that PEG is depleted near the interface. Survanta has a more compact lattice corresponding to a small increase in the surface pressure. These findings give insights into the biophysics and molecular basis for acute respiratory distress syndrome treatment: (1) albumin adsorption creates a physical barrier that inhibits lung surfactant adsorption, (2) PEG in the subphase generates a depletion attraction between the lung surfactant aggregates and the interface that enhances lung surfactant adsorption, and (3) the structure or properties of the lung surfactant monolayer are substantially unchanged. The research will aid in the rational development of improved treatments for acute respiratory distress syndrome.

Reference: "X-Ray Diffraction and Reflectivity Study of the Competitive Adsorption of Lung Surfactant and Albumin," *Biophysical Journal* **97**, 777 (2009). The DOE Office of Basic Energy Sciences funded the Los Alamos scientists.

Zhao. . . continued from page 1

High-pressure techniques combined with neutron scattering enable Zhao and scientists like him to study changes in clathrate structure at the atomic level and monitor the movement of carbon dioxide, hydrogen, and other gas molecules in and out of the ice-like framework as pressure and temperature conditions change.

"We are faced with three fundamental questions to answer in this research," Zhao said, in discussing the challenges of this research. "First, we must understand how the gas molecules are being trapped inside the crystalline clathrate cages; second, we need to map out the pressure and temperature stability field of the methane hydrate system; and third, we must understand the kinetics of its formation and decomposition."

Zhao is also involved in applying high-pressure techniques to design new nanostructured superhard materials with novel and enhanced properties. The diamond-silicon carbide nanocomposites Zhao developed, for example, increase fracture toughness by more than 80 percent and have widespread applications in the mining and petroleum industries.

He also conducts energy conservation studies involving lithium batteries. To understand energy density and power density of battery materials, Zhao uses in situ time-resolved neutron-scattering techniques to observe how the lithium ion behaves during the battery's charge and discharge process.

Balancing fundamental physics research with engineering innovations, Zhao takes advantage of the unique high-pressure neutron scattering capabilities at the Los Alamos Neutron Science Center (LANSCE).

LANSCE offers Zhao and his colleagues the ability to work with a high-flux neutron beam. Combined with Zhao's design and development of a variety of special high-pressure cells for neutron scattering, the Laboratory provides scientists state-of-the-art equipment and resources unavailable elsewhere in the country and has attracted researchers from around the world to Los Alamos to carry out various experiments.

Zhao, who came to Los Alamos as a postdoctoral researcher in 1994, studied geosciences at Peking University, in China, before becoming a visiting research fellow at the University of California, Berkeley. He earned his doctorate in geophysics from the State University of New York at Stony Brook.

Zhao has received four patents and has two pending and is a two-time recipient of the DOE/NNSA Defense Program Award of Excellence. "Unlike many LANL scientists, [Zhao] has been extremely aggressive in patenting his innovations," said Don Hickmott of Earth and Environmental Sciences Division. "He received a LANL distinguished licensing award for one of his patents."

This 2007 award was for his for work on superhard ultratough nanocomposites, a novel, nanostructured type of composite that consists of diamond particles embedded in a matrix of nanocrystalline silicon carbide. Zhao was recognized for demonstrating outstanding success in the process of transferring his technology to industry through an exclusive license with US Synthetic, a company that leads the industry in the development and production of polycrystalline diamond cutters for oil and gas exploration.

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Celebrating service

Congratulations to the following AOT and LANSCE employees celebrating service anniversaries this month:

Luis Lopez, AOT-RFE	30 years
John Gilpatrick, AOT-IC	25 years
Luc Daemen, LANSCE-LC	20 years
Mark McMillen, AOT-OPS	15 years
Leilani Conradson, LANSCE-DO	10 years

HeadsUP!

ChemLog link

The Laboratory's chemical inventory system (ChemLog) Web site can now be through an easy to find link on the Laboratory's home page, under the "Quick Links/Safety" section at the bottom of int.lanl.gov.